On-Site Treatment of Wash Water at Arnold AFB Reduces Costly Disposal

Randy Jones, Environmental Engineer, Sverdrup Technology, Inc./AEDC Group
1100 Kindel Drive, Arnold AFB, TN 37389-1805, (931) 454-4602, jonesre@hap.arnold.af.mil
Steve Kent, CleanRack Division Manager, Eco Soil Systems, Inc.
8807 Glenside Street, Huntersville, NC 28078, (704) 947-9996, skent01@worldnet.att.net

Annual Joint Services Pollution Prevention Conference & Exhibition, San Antonio, Texas, August 1998

This paper will describe a water treatment system designed to process wash water generated during propulsion wind tunnel (PWT) cleaning at Arnold Air Force Base. Following a brief discussion of the waste generating process, analytical results of an on-site pilot test will be reviewed. Integral components of the treatment system were selected based on the demonstrated success of the pilot test. In conclusion, the paper will detail the flow path of processed water from generation to final product and summarize projected operating costs.

Introduction

Arnold Air Force Base (AAFB), located in Middle Tennessee, is the site of Arnold Engineering Development Center (AEDC). AEDC is one of the nation's leading aerodynamic and propulsion research and test facilities. Maintaining a diverse array of test units including: propulsion wind tunnels, rocket and turbine engine test cells, space environmental chambers, high temperature arc heaters, and ballistic ranges in a clean and safe environment can pose unique challenges, especially when it comes to pollution prevention and waste minimization. Wash waters generated during propulsion wind tunnel (PWT) cleaning annually generate approximately 30,000 gallons of waste. Primary contaminants include dirt, grit, detergents, heavy metals, and both free and emulsified oils. In an effort to eliminate costly off-site disposal, a 400 gallon per hour waste water treatment system was designed and constructed to process the wash water prior to permitted release. Major processes incorporated into the system design include oil water separation, emulsion splitting and encapsulation, mechanical filtration, and advanced chemical oxidation. Figure 1 is a photograph of the combined treatment system.

Figure 1 – PWT Wash Water Treatment System

Wash Water Generation and Characterization

PWT 16T is a closed loop wind tunnel with a footprint of approximately 200 ft by 400 ft and diameter ranging from 36 ft to 55 ft. During the course of testing, oil is introduced from bearings, pump seals, and numerous hydraulic systems and their fugitive leaks. During maintenance and shutdown periods, cumulative contamination due to dust, paint, and dirt can contribute to environmental problems. This dirty environment can lead to both personnel safety (i.e., slip and fall hazards) and test related problems such as oil and grit build-up on test models. The only effective cleaning process to date includes:

a) Spraying a cleaner/degreaser on the tunnel walls
b) Allowing sufficient contact time (2-3 hours) on oil dried surfaces, and
c) Rinsing the walls to sufficiently remove the deposits and cleaner/degreaser

Resulting wash waters are collected at tunnel low points, rough screened, and drained into a 1,500 gallon polyethylene container to await characterization. Representative samples are collected from each tank by recirculating a minimum of three tank volumes and pulling samples from the flowing return stream. Collected samples are taken to the on-base chemistry laboratory and analyzed for metals per Method 1311 of SW-846, Toxicity Characteristic Leachate Procedures (TCLP). Other analyses such as pH, Turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Volatile Organic Compounds (VOC), and Oil and Grease are periodically monitored.

The following studies show the degree of cleaning and subsequent contamination is largely dependent on the cleaner used. Over the years maintenance personnel have settled upon two cleaners, Cytra Klean and So-Pro. Cytra Klean is the preferred cleaner due to its adhesive action on the oily tunnel walls and degreasing ability. Cytra Klean detergent is comprised of citrus terpines (oils derived from the skins of citrus fruit, extracted during the process of concentrating). These light oils are the active ingredients in the cleaning action as well as the ingredients that create such a tight chemical emulsion.

Pilot Test Results

In September 1996, AEDC maintenance personnel cleaned representative PWT sections with both Cytra Klean and So-Pro cleaners. Approximately 1,500 gallons of each waste stream were collected. Within two weeks of waste generation, a full-scale, on-site pilot test was conducted to evaluate the effectiveness of emulsion splitting encapsulation and advanced chemical oxidation (ACO) on the removal of contaminants from tunnel cleaning waste. These processes are outlined in a proceeding section. Representative samples were obtained of each tank and the analytical results are summarized in columns 2 and 7 of Table 1. Both wet and dry sludge samples were analyzed and are tabulated in columns 5, 10 and 11. Note in most cases, sludge TCLP results were well below influent wash water TCLP concentrations. One sample was obtained to characterize the emulsion splitting encapsulation system discharge prior to further conditioning. This data, summarized in column 8, demonstrated a significant improvement in water quality (99.5% improvement for oil & grease, and >85% for lead). Samples were taken at various times during recirculation through the ACO system. These samples are summarized in columns 3, 4, and 9. This data demonstrates a significant overall improvement in water quality with a minimum recirculation time of 8 hours (approximately 3 to 4 tank volumes).

Table 1 - Analytical Data

1	2	3	4	5	6	7	8	9	10	11
Description	So-Pro Waste H2O	Finish H2O at 8hr	Finish H2O at 24hr	Dry Filter Cake		Cytra Klean waste H20	Outlet of VA-2000	Finish H2O at 12hr	Dry Filter Cake	Wet Filter Cake
pH (pH units)	7.96	7.85	8.3			7.6	7.6	4.5		
Turbidity (NTU)	560	7	6			19,000	9			
TSS (ppm)	441	14.6	7.5			1498	26	7		
TDS (ppm)	1420	2086	1700			2556	3194	6205		
Oil & Grease (ppm)	28.2	0.4	<0.2			8835	48	0.6		
Metals - Total (ppm)										
As		<0.07	<0.07				<0.7	0.09		
Ba		<0.001	<0.001				0.04	0.02		
Cd		<0.002	<0.002				0.04	<0.002		
Cr		<0.01	<0.01				<0.10	0.03		
Pb		0.05	0.07				<0.40	<0.02		
Se		<0.01	<0.01				<1.0	<0.02		
Ag		0.008	0.007				0.08	<0.02		
Metals - TCLP (ppm)										
As	<0.070	<0.07		<0.14		<0.07	<0.7	0.09	<0.07	<0.14
Ba	0.04	0.002		0.13		0.7	0.01	0.02	0.14	0.19
Cd	0.09	<0.002		0.03		0.54	0.03	<0.002	0.15	0.15
Cr	0.26	<0.01		<0.02		0.38	<0.10	0.03	0.02	0.02
Pb	1.23	<0.04		<0.08		2.85	<0.40	<0.02	<0.04	0.41
Se	<1.0	<0.10		<0.20		<1.0	<1.0	<0.02	<0.10	<0.20
Ag	<0.05	<0.005		<0.01		0.03	0.1	<0.02	<0.005	<0.01

Results shown in column 9 reflect water processed through a multi-media filter at the vendor laboratory. The purification loop booster pump was undersized and could not pump the processed (Cytra Klean) water through the multi-media filter. The vendor reported that tank corrosion during transport and storage, prior to processing, was probably responsible for the large increase in TDS.

The system, as tested, was a fully automated 500 gallons per hour batch treatment system. The system was primarily operated in the manual mode to determine processing times for the two streams tested. Table 2 is a summary of operational data and consumable material usage.

Table 2 - Summary of Operational Data and Consumable Use

Detergent Type	Process Time (min)	Encapsulant Usage (g/gal)	Filter Paper Usage (yards)	Gallons Processed
So-Pro	23	23	3	1500
Cytra Klean	39	30	15	1500
Combined Average/Totals		**27**	**9**	**3000**

Note the additional processing time and encapsulant usage for Cytra Klean laden wash water. This factor along with redundancy afforded by a backup system and additional storage led to the design of two separate influent receiving and process water storage tanks. Table 3 is a summary of processing costs based upon gallons processed (3,000 gallons) and consumables expended.

Table 3 - Cost per Gallon (Excluding Manpower Requirements)

Detergent Type	Encapsulant Amount (lb)	Encapsulant Cost ($/lb)	Cost per Gallon (¢)
So-Pro	75	$2.^{35}	12¢
Cytra Klean	100	$2.^{35}	16¢

Process Description - Unloading

Wash water is transported to the treatment system and unloaded via an air operated diaphragm pump. A diaphragm pump was selected to minimize further emulsion of settled wash water. Two 2,000-gallon internal conical tanks constructed of high-density polyethylene (HDPE) are used to store the wash water prior to treatment. Internal conical construction eliminates the need for external support stands saving space, reducing maintenance requirements, and enhancing cleanout of collected solids. Chemical and mechanical emulsions may, over time, separate from the aqueous phase. This separation is caused by the lighter specific gravity of some contaminants (i.e., oils, citrus-based cleaners, etc.) vs. water. Each tank is equipped with a surface mounted belt skimmer to collect these contaminants for reuse, recycling, and/or disposal.

Process Description – Pre-Filtration

A fully automated emulsion splitting encapsulation system based on the physical-chemical treatment process[1] is employed as both a pre-filter and primary treatment. Emulsion splitting, coagulation, flocculation, adsorption, waste encapsulation and solidification of resultant sludge are all employed during this process. Wash water from the selected tank is transferred, level controlled to the treatment reactor. After a brief mixing period, an auger feeds the desired amount of emulsion splitting agent (flocculent) to the reactor volume. The amount of splitting agent added is fully adjustable based on user knowledge of a particular waste stream or jar testing results.

The reaction of wash water/splitting agent mixture is hydrodynamically promoted by a variable speed mixer allowing dispersed (i.e., turbid particles, metals, oil drops, etc.) and dissolved noxious matters (i.e., tensides, water soluble solvents, emulgated hydrocarbons, etc.) to agglomerate and form a microfloc. These flocs continue to join, bridging from one surface to another and binding the individual particles into larger agglomerates called macrofloc. Flocculation is promoted by slow mixing. A high mixing velocity can shear the floc, reintroducing contaminants into the wash water. Rarely do sheared floc re-form to their optimum size and strength. Not only does flocculation increase the size of the particle but also affects the physical nature as well. Sludges and slurries, when flocculated, dewater at faster rates because of the less gelatinous structure of the floc. [2]

After flocculation is optimized, mixing is stopped and a sedimentation period allows the floc to settle in the reactor. There are three stratified layers in the reactivation vessel. The top layer consists primarily of clean water but may contain floating solids (i.e., undissolved clay, plastic, etc.) and free oils in heavily contaminated water or if an excessive quantity of flocculant was added. The middle layer contains cleaned water (clear well) and is the desired product. The bottom layer is the resulting sludge and possible end use of this material will be discussed later in this section. Water in the clear well is pumped through a 25-micron filter to one of two 2,000-gallon process water storage tanks. Based on analytical results, the processed water can be reused, discharged to a permitted outfall, or retained for additional treatment.

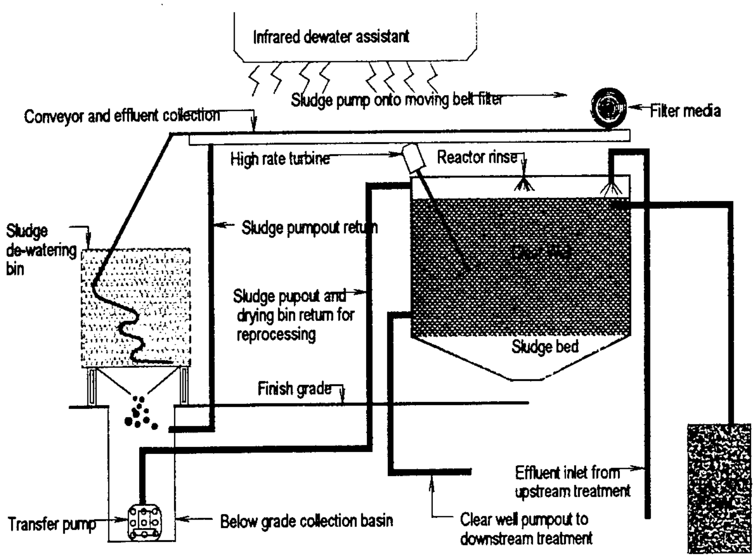
---

[1] The Nalco Water Handbook describes Physical-Chemical treatment as a process by which waste effluent is taken into a rapid mix and flocculation zone where a large dose of chemicals is added to produce a massive chemical coagulation and flocculation. Nalco Water Handbook, second edition, copyright 1988. McGraw-Hill Inc.

[2] Flocculation section of the Nalco Water Handbook referenced above.

The sludge layer, containing encapsulated contaminants, is pumped onto a moving belt particulate filter for de-watering. As sludge accumulates on the filter belt, the belt automatically advances exposing new filter paper. Filtered water gravity drains to a de-watering sump and is pumped back into the original storage tank for reprocessing. Filter paper and sludge are sent to a bin for further de-watering. An infrared heater is mounted above the de-watering bin to assist in the process. De-watered solution gravity drains to a sump and is pumped back to the original storage tank for reprocessing. The de-watering bin is forklift accessible and self-dumping with a volume of approximately 2 cubic yards. Approximately 8,000 to 10,000 gallons of water can be processed before the bin is full. A national concrete/masonry company is currently evaluating the resulting sludge as a potential aggregate to their brick making process. Figure 3 is a schematic representation of the emulsion splitting process.

Figure 3 – Emulsion-Splitting Encapsulation Pre-Filter



Process Description – Post Treatment

Final treatment is available to water stored in the process water storage tanks. Advanced Chemical Oxidation (ACO) and mechanical filtration were selected for this purpose. ACO is a group of processes utilizing ultra-violet (UV) light with catalyst oxidizers hydrogen peroxide and ozone to precipitate dissolved metals and oxidize organic contaminants to carbon dioxide and water. The following excerpt provides an excellent summary of this process. "UV light catalyzes the chemical oxidation of organic contaminants in water by its combined effect upon the organic substances and reaction with hydrogen peroxide. First, many organic contaminants that absorb UV light may undergo a change in their chemical structure or may become more reactive with chemical oxidants. Second, and more importantly, UV light catalyzes the breakdown of hydrogen peroxide to produce hydroxyl radicals, which are powerful chemical oxidants. Hydroxyl radicals react with organic contaminants, destroying them and producing harmless carbon dioxide, halides, and water by-products. The process produces no hazardous by-products or air emissions."[3]

Two multi-stage filters are installed upstream of the UV lamp to provide maximum penetration of UV light through the water. This penetration is critical to gain full advantage of bond destruction by direct photolysis. Any remaining waterborne impurities (i.e., turbidity, TDS, foaming, etc.) reduce absorption of UV radiation by the treated water and lower the hydroxyl radical production. Each multi-stage filter consists of a coalescing media, 25 micron poly spun fiber filter, 400 cubic inches of activated carbon, and a hydrocarbon purge (vent).

Operation & Maintenance Costs

While the treatment system is fully automated, it's the author's opinion that at least one dedicated/qualified waste water treatment plant operator will be required to operate or ensure smooth operation of the system. AEDC plans to operate the system with existing personnel and expects no additional staffing requirements. A schedule of estimated operation & maintenance costs are listed in Table 4. These include annualized costs of consumable supplies, operation and maintenance personnel, and a maintenance contract (optional). Utility costs are excluded.

Table 4 - Annualized Operation & Maintenance Costs[4]

Description	Units Required	Unit of Issue	Frequency of Replacement	Cost per Unit	Annual Cost
Operating Supplies					
Hydrogen Peroxide	12	55 gal	Monthly	$217.50	$2,610.00
Flocculant / Encapsulant	36	50 lb	As needed	$117.34	$4,224.00
Filter Paper	8	Roll	As needed	$175.00	$1,400.00
Operation and Maintenance Personnel					
Operations	75	hrs	N/A	$30.00/hr	$2,250.00
Maintenance	75	hrs	N/A	$30.00/hr	$2,250.00
Maintenance Contract - Optional					
Vendor	1	ea	Monthly	$2160.00	$2,160.00
Total Annualized Operations & Maintenance Costs					**$12,734.00**
Total Cost per Gallon (30,000 gallon production rate)					**42¢**

At present, the approximate cost to dispose of non-hazardous waste is 60¢ per gallon. This amounts to cost savings of approximately $7,000 per year based on a waste generation rate of 30,000 gallons. The system is presently undergoing performance verification and it is projected that existing capabilities will be diverse enough to treat an additional 70,000 gallons of AEDC generated non-hazardous waste at a comparable cost. This would increase the annual cost savings to over $20,000 per year.

[3] Quote captured from the "Peroxide Advanced Oxidation Wastewater Treatment" article downloaded from the Envirosense Internet web site at HTTP://clean.rti.org

[4] Annualized cost based upon a 30,000 gallon per year production rate.